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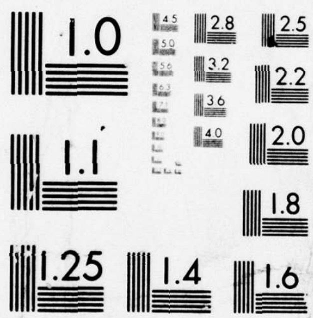

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INDIVIDUAL STUDY PROGRAM

IMPROVEMENT OF WEAPON SYSTEMS
RELIABILITY THROUGH
RELIABILITY IMPROVEMENT WARRANTIES

STUDY PROJECT REPORT

PMC 77-1

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Improvement of Weapon Systems Reliability through Reliability Improvement Warranties

Individual Study Program

Study Project Report

Prepared as a Formal Report

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Program Management Course

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by

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DEFENSE SYSTEMS MANAGEMENT COLLEGE

STUDY TITLE: IMPROVEMENT OF WEAPON SYSTEM RELIABILITY THROUGH RELIABILITY IMPROVEMENT WARRANTIES

STUDY PROJECT GOALS: To investigate evolution of reliability Improvement Warranties (RIWs) and current USAF RIW applications to assess potential for reducing costs of ownership and to provide initial lessons learned.

STUDY REPORT ABSTRACT:

The report outlines the basic causes of poor weapon systems reliability including requirements that demand greater improvements in capability over improvements in reliability, inadequate development testing, and the lack of incentive for producers of military hardware to increase reliability.

The use of warranties by commercial airlines and introduction into the Department of Defense is explored.

An analysis of two USAF applications of RIW, the F-111 displacement gyro and the ARN-118 TACAN is conducted utilizing data current through the end of CY 1976 in order to extract initial lessons learned.

The report recommends continued emphasis on testing improvements, higher initial utilization of newly warranted equipments, education and evaluation of maintenance and supply personnel in RIW procedures, higher priorities for movement of failed units to contractor facilities, evaluation of a Swedish approach which utilizes military depots and existing logistics pipelines for servicing RIWs and continued allocation of resources to improve reliability state-of-the-art.

KEY WORDS: RELIABILITY
RELIABILITY IMPROVEMENT WARRANTY
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EXECUTIVE SUMMARY

The Reliability Improvement Warranty (RIW) is a procurement methodology which is currently being tested by the Department of Defense. The RIW is characterized by a fixed price contract for support and reliability improvement of a system during an initial period of service, usually three to five years. The warranty can include Mean Time Between Failure (MTBF) guarantees which maximize contractor liability by requiring provisions of additional spares at no cost to the government in case reliability goals are not achieved. The contractor is incentivized to build in reliability and improve reliability during the life of the warranty. Investigation of current applications within the Air Force indicates either good initial reliability or reliability growth; however, it also reflects less than desirable utilization rates of warranted equipment, excessive shipment times to contractor's repair facilities, and general unfamiliarity with RIW concepts and procedures by field maintenance and supply personnel. Concern has also been expressed on inadequate pricing procedures for the procurement of RIW arrangements and limitations on wartime utilization rates caused by non-organic support for critical components of major weapon systems.

This report recommends continued emphasis on testing improvements, higher initial utilization of newly warranted equipments, education and evaluation of maintenance and supply personnel in RIW procedures, higher priorities for movement of failed units to contractor facilities, evaluation of a Swedish approach which utilizes military depots and existing logistic pipelines for servicing RIWs and continued allocation of resources to improve reliability state-of-the-art.

ACKNOWLEDGEMENTS

This report would not have come into existence had it not been for the full support of the Directorate of Reconnaissance and Electronic Warfare, Deputy Chief of Staff for Research and Development, HQ USAF, for freeing the author to attend the Defense Systems Management College. For this, I thank the Directorate and my fellow action officers who have shouldered an additional burden in my absence.

Nor would the report have come into being without the patience and understanding of my wife and companion who kept the hearth warm and the children at bay as I embarked on yet another crusade.

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SECTION I

INTRODUCTION

At the tip of the tongue of every DoD executive, military commander, and acquisition program manager is the word "reliability". Reliability improvements appear to be the most efficient and available means to slow the rate of increasing costs of ownership of military equipment. In addition, significant improvements in reliability can force multiplier effects by assuring that possessed equipment will be ready for use when needed and will operate without failure in rigorous environments of military operations at the same time reducing the characteristically large logistic tail.

One potential solution to the reliability problem is the Reliability Improvement Warranty (RIW) which the Department of Defense is currently testing. Initial applications have indicated promise but no panacea.

Purpose of the Study Report

The major portion of this report will be dedicated to outlining the factors that have resulted in low weapon systems reliability, tracing the evolution of RIW within the Department of Defense and by a subjective analysis of two Air Force RIW applications. The test cases chosen, the FB-111 Displacement Gyro and the ARN-118 TACAN, were selected to get as broad a view of the warranty period as possible, the gyro being a mature system now transitioning from warranty to organic support and the TACAN about one year deep into its initial warranty period. Both systems have valuable lessons learned which may be beneficial to managers of future RIW applications. It will be shown that RIW attack some of the basic causes of poor reliability and precipitate other problems which require solution.

Definitions:

Elapsed Time Indicator - A timing device directly mounted to a unit of equipment which indicates the cummulative hours of operation.

False Alarm - A unit thought to be inoperative which is subsequently found to be operational. In RIW applications units returned to the contractor for repair, but which are found to be serviceable contribute to the false alarm rate. Normally, false alarm rates exceeding a contract specification are chargeable to the government.

Life Cycle Cost (LCC). "The LCC of a system is the total cost to the goverment of the acquisition and ownership of that system over its full life. It includes the cost of development, acquisition, operation, support, and where applicable, disposal." (23:2)

Heads Up Display (HUD). A projected display of critical flight parameters through which a pilot looks while engaged in ground target attack. The HUD system decreases the probability of loss of visual contact with the target and/or pilot distraction while engaged in maximum performance manuvers in close proximity to the ground.

Inertial Navigation System (INS) - A navigation system based on an erected stable element which measures acceleration vectors and computes velocity and position.

Mean Time Between Failure (MTBF) - A time expressed in hours quantified by dividing mean operating hours by the mean number of failures.

Reliability Improvement Warranty (RIW). "A provision in either a fixed price acquisition, or fixed price equipment overhaul contract in which:

1. The contractor is provided with a monetary incentive (by being allowed to retain all savings accrued due to reduced contractor support costs during the period of warranty) throughout the period of the warranty to improve the production design and engineering of the equipment so as to enhance the field/operational reliability and maintainability of the system/equipment.

2. The contractor agrees that, during a specific or measured period of use, he will repair or replace (within a specified turn-around time) all equipment that fails (subject to specified exclusions if applicable). (25: Enclosure, p 4)

TACAN. - An acronym for Tactical Air Navigation.

Turn-Around-Time. - Time interval from receipt of failed unit at the manufacturer's dock until receipt of the repaired unit at a government bonded warehouse.

The Causes of Unreliability

The most effective problem solution will counter the original causes of the problem. It is appropriate that before an investigation of RIW applications is conducted, that the question, "What are the basic causes of poor reliability?", be answered.

Capability Requirements that Push the State-Of-the-Art

Military equipment in our continuing technological explosion of the 20th century is more complex, has more components, does more, and has to deal with environments of several orders more demanding than systems had to contend with only 20 years ago. In our quest for military capability to defend against perceived threats, technological breakthroughs have been converted to large advances in capabilities of weapon systems. In fact, most technological gains have been applied to increased weapon system's performance with inadequate emphasis on reliability and ease of maintenance. Robert F. Trinkler, from the Office of Federal Procurement Policy, Executive Office of the President, emphasized this fact by stating:

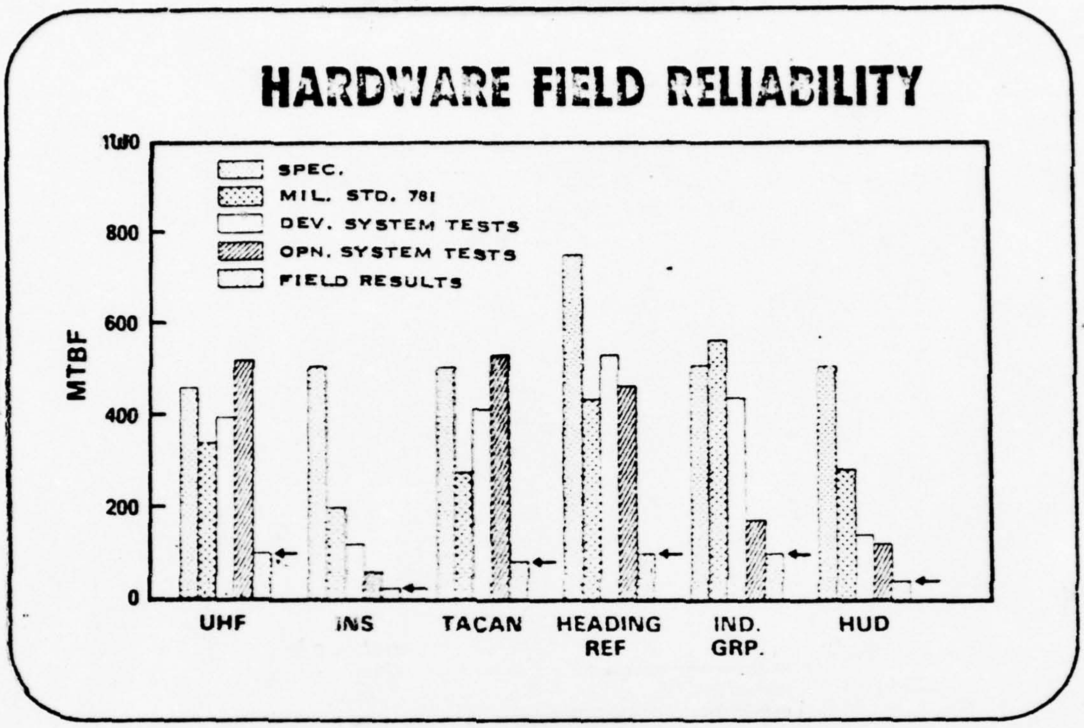
> The real tragedy of these past situations is that the technology for reliability was more easily attainable than the basic technology of the equipment itself (19:23).

The military services must accept a great deal of responsibility for the typically low Mean Time Between Failure (MTBF) currently being experienced. It is primarily due to the perceived need to push the state-of-the-art and modernize now without sufficient consideration to the price which must be ultimately paid to support the Buck Rogers ideas of yesteryear.

Disparity Between Test Results and Operational Reliability

Equipment is not being designed for or tested in an environment similar to that in which it will be ultimately employed (12-25).

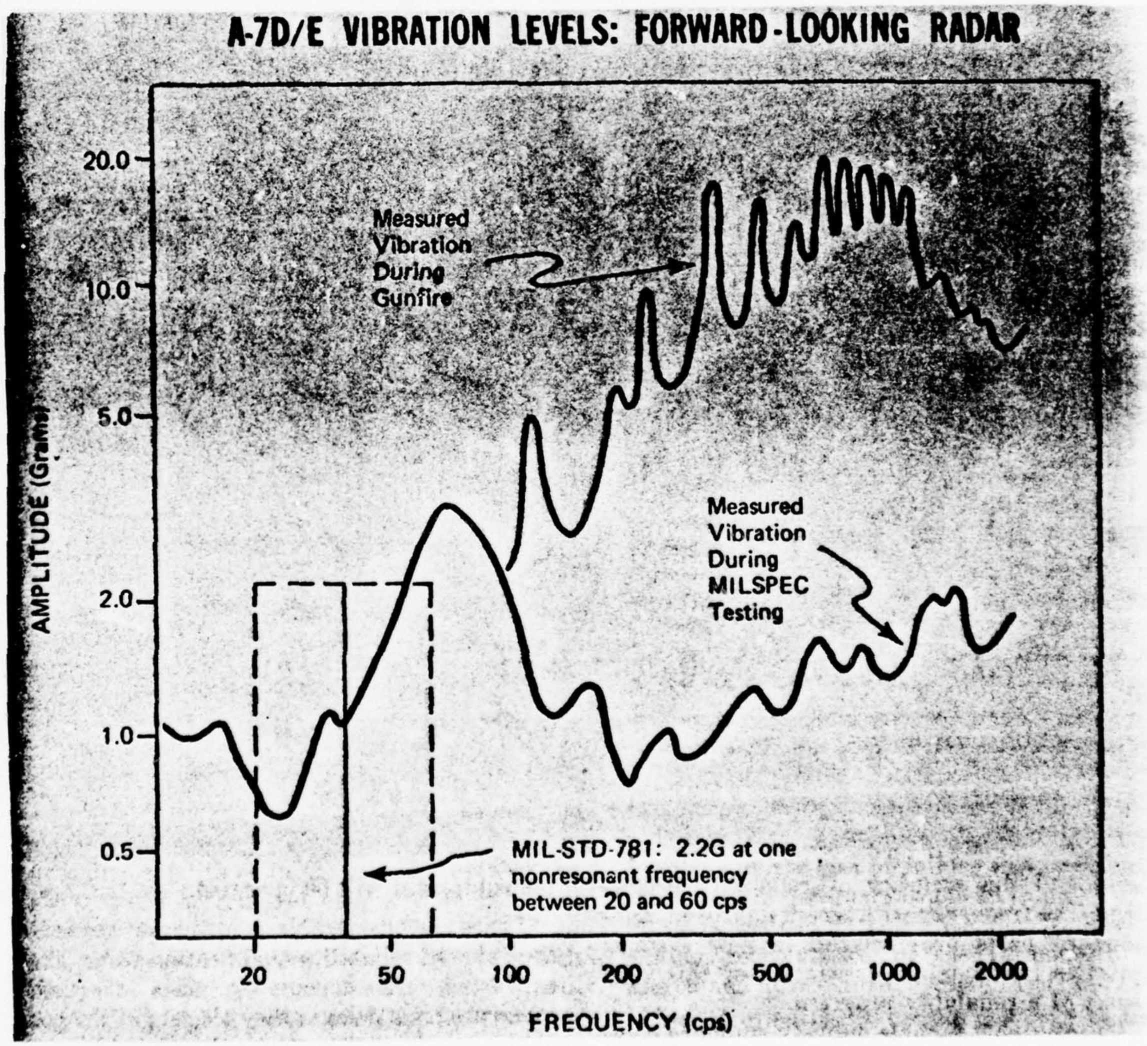
Acquisition Applications Seminars (held at Hq USAF during 1976) sponsored by the Department of the Air Force and extensively supported by the ARINC Research Corporation, pointed out the broad disparity between testing and operational environments by documenting the wide discrepancies in failure rates. The following chart indicates the significantly lower MTBFs experienced in operational service than experienced in testing (1-3).



The standard which currently specifies the amount and degree of testing required was released in the early 1960s to yield economies in necessary but expensive environmental test equipment. This standard, MIL-STD-781 was more designed to detect workmanship errors than to simulate operational environments where equipment would ultimately be used. MIL-STD-781 is currently being revised to address this deficiency (2:32).

Contractor testing facilities are not currently required to simulate operational environments and, therefore, surprise component failures tend to show up after insertion into operational use.

Lt Gen Robert T. Marsh, Vice Commander, Air Force Systems Command, stressed this point by using the following chart which shows the A-7 Radar Testing Environment required by MIL-STD-781, the environment used for test and the real world environment in which the A-7 radar ultimately had to operate (12:27).



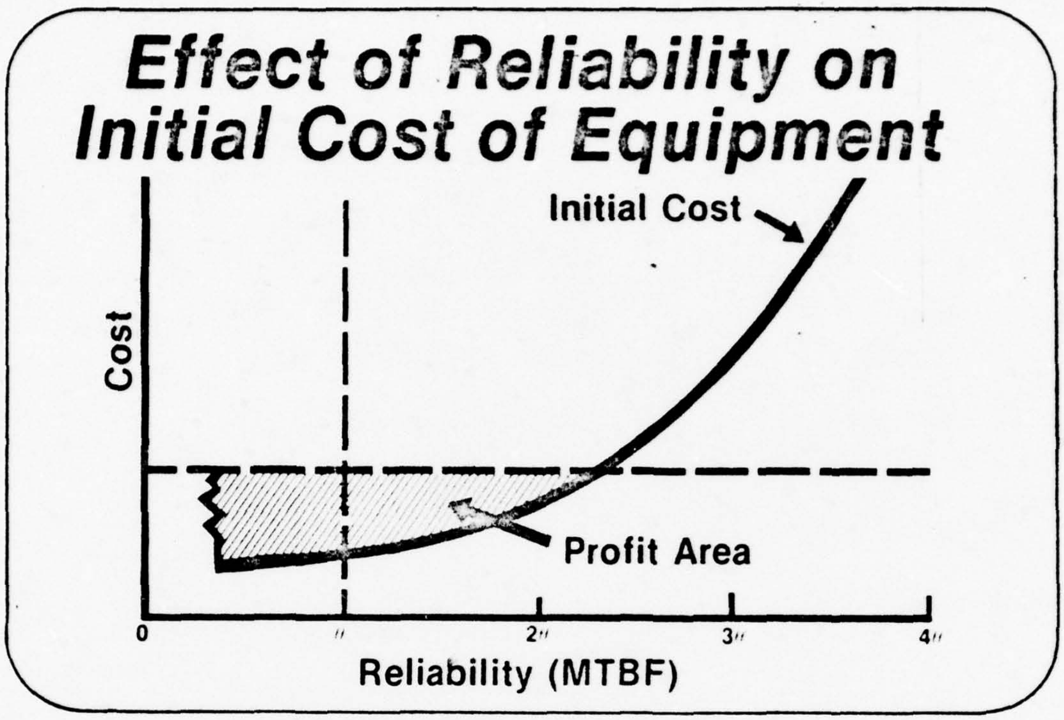
Lack of Incentive to Build in Reliability

In the preceding example, the contractors did more testing than the specification required but still fell short of realistic operational environmental testing. Under current guidelines, however, the contractor should, in no way, construe this shortfall to be criticism of his procedures. The contractor is obligated to his shareholders to develop a piece of equipment at the least expense and at the lowest acceptable reliability. The government expects the contractor to produce a unit at the lowest cost to the government to do a given job (14).

Under fixed price procurements the contractor must reduce costs to increase his profit. Reliability becomes an easy trade-off victim as shown by the following statement:

> ...Today's procurement practice, with the emphasis on low initial price, causes vendors to supply the lowest reliability that will pass the procurement acceptance requirements. The vendor is economically driven to this position, his maximum profit being derived from such strategy (4:4).

The following chart graphically demonstrates this phenomenon (1:8-19).



The contractor also has an eye on the downstream spare parts market, which a production system represents. Any increases of reliability would actually be counter productive to participation in this future market.

The current weapon's acquisition system, when operating at the optimum, will be producing equipment that just meets--not beats-all specifications including reliability. There is no risk to the contractor, beyond damage to his reputation, if the failure rate experienced in operational service is significantly higher than might have been predicted by

earlier qualification and developmental/operational testing. The government has traditionally absorbed this risk and the resultant higher maintenance and support costs.

If the basic causes of poor reliability are requirements that "push the state-of-the-art", unrealistic testing and qualification, and lack of incentive to developmental/production contractors, then how does the RIW counteract the causes of poor reliability?

In the following and succeeding sections of this report, it will be shown how the RIW evolved into a tool that addresses the causes of poor reliability and the current status of RIW applications in the Air Force.

SECTION II

Evaluation of Reliability Improvement Warranties

It is interesting to note that in 1967, a consumer of avionics equipment, Pan American Airlines, and a vendor of like equipment, Lear Siegler, Inc., (LSI) simultaneously and independently initiated a contractual method which incentivized a manufacturer toward improved reliability (17:1) (10:51). These initial efforts evolved into today's application of RIW within the Department of Defense.

The Airline Experience

Pan American, when faced with a major purchase of over one billion dollars for 33 Boeing 747 aircraft, was highly concerned with the risks associated with the unpredictability of future support costs because of poor reliability. In previous experiences with one year warranties, Pan American had noted:

> It is the vendor who decides whether he will insert in his product a subcomponent or part that will survive for at least a three year period. There have been cases in the past, where as a matter of attempting to improve a price position or improve a profit ratio, vendors would insert piece parts that were known, or suspected to have a life of more than one (1) year, but less than eighteen (18) months. This was the case when warranties were of one (1) year duration (17:2).

In order to assure reasonable support costs for their newly acquired 747s, Pan American was willing to pay their vendors a fixed amount per flying hour to pass the risk of high support costs. Pan American, in exercising their concept of "total product support", incentivized their suppliers to build in reliability and to improve reliability throughout the duration of the warranty. This benefited the supplier by allowing him through reliability improvements to reduce his own support costs and eventually pocket the remainder of the fixed product support price.

By 1973, Product Support Agreements, tendered by Pan American, included MTBF guarantees. The guarantees provided that specified MTBFs would be achieved by the end of normally five (5) year warranty periods. If guaranteed MTBFs were not achieved then vendors would have to provide additional spares and reliability modifications at no cost to Pan American. George E. Hiller, Project Manager from Pan American, reported:

> Reliability, the real result of this program has always been improved .... (17:5).

The Navy Experience

Prior to 1967, Lear Siegler Inc (LSI) had been under a cost contract for some years to the U.S. Navy to repair CN 994A/AJB-3 gyroscope platforms used in Navy A-4 Skyhawk and F-4 Phantom aircraft. Payments were based on negotiated rates for labor, overhead, profit, etc.

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In 1967, LSI proposed a new concept which included a fixed price for overhaul of the gyroscopes over a long term operating period. The concept was called a Failure Free Warranty (FFW) (7, 2).

The Navy accepted the LSI offer and established a warranty for 1500 field hours over a five year period for 800 gyroscopes. The experience was so successful that the contract was renewed in July 1973 for an additional 1500 field operating hours and six years (7:5). According to Aviation Week and Space Technology,

> Over...(the first) five year period, the gyro platform experienced a 33% increase in mean-time-between-failure and a 40% reduction in unit repair cost....Both the Navy and Lear Siegler were pleased with the contract arrangement (9:51).

This Navy experience, under the guidance of Mr. Oscar Markowitz from the Navy Aviation Supply Office, was the first DoD application of a reliability warranty. The improvements in reliability and cost savings generated a great deal of interest within the Department of Defense.

In 1969, the Air Force let a contract with LSI for the F-111 Displacement Gyro which included a FFW for 3,000 Elapsed Time Indicator (ETI) hours or five years, whichever occurs first. This contract is discussed in detail in a following section of this report.

Department of Defense Trial Use of RIW

The Department of Defense was not overly enamored by the term-Failure Free Warranty-since the term implied there would either be no failures or that the warranty was free - highly desirable, but improbable goals. Since the major thrust of the contractural method was to initially build in high reliability and improve reliability during an initial period of operational use, the term Reliability Improvement Warranty was preferred and eventually adopted (15:18).

In August 1973, the Assistant Secretary of Defense (Installations and Logistics) directed the trial use of warranties by the Services "in the acquistion and initial operational support of a number of Electronic Subsystems." (24:1)

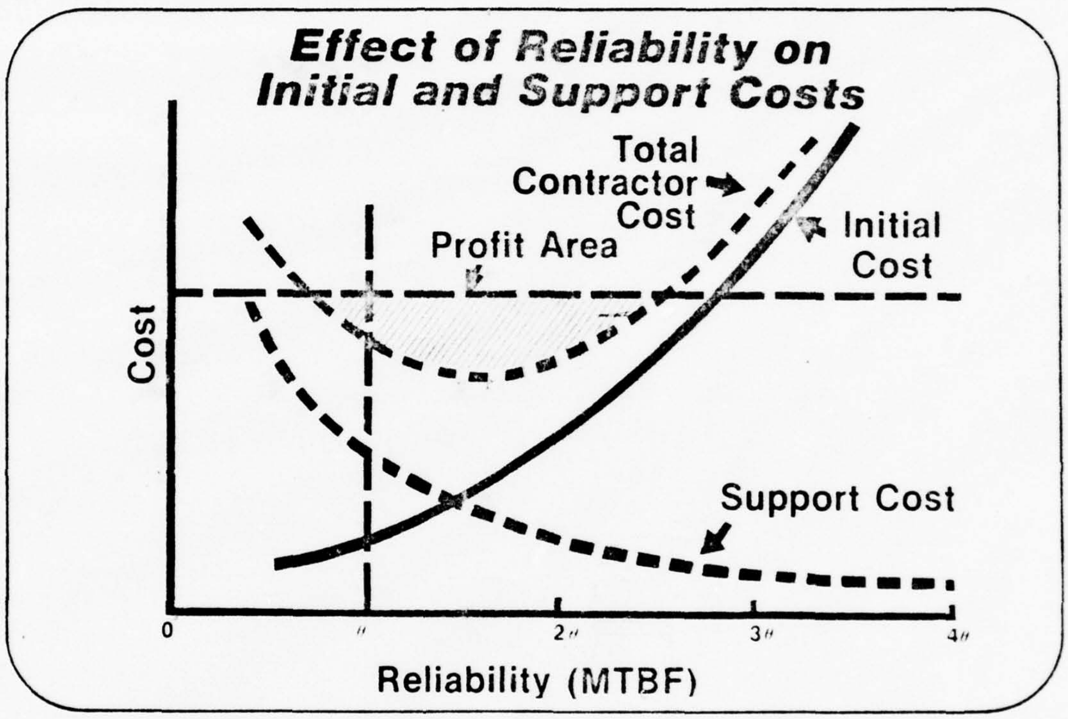
Air Force Guidelines for Application of RIW

In response to the DOD direction, the Directorate of Procurement Policy, Hq USAF, published "Interim Reliability Improvement Warranty (RIW) Guidelines", in July 1974. The publication described the RIW objective as follows:

> The essence of the RIW philosophy is that during the period of warranty coverage, for a fixed price, contractors will be encouraged to improve the reliability and to reduce the repair costs of their equipment through the mechanism of 'no cost' (to the Government) Engineering Change Proposals (ECPs)....once a fixed price is established for the RIW the actual profit realized by the contractor is dependent upon the equipment's reliability and maintainability, in-service use, plus any improvements that he can make in its reliability and maintainability so as to keep the number and cost of repairs as low as possible.

An RIW becomes a contracting technique by which the government derives the benefits of improved reliability and maintainability for each additional dollar that the contractor earns." (italics added) (21:4)

This approach is graphically portrayed below (1:8-21);



The horizotal dashed line represents the price on a firm fixed price contract. The descending dashed line indicates that with increasing reliability, contractor (and eventually government) support costs decrease. This increase in reliability, however, is at an increase in initial cost (ascending solid line). The contractor is thus incentivized to work toward the middle of the "U" shaped curve to maximize profits. This is achieved by continuous

trade-offs between the cost of including a reliability improvement and the overall reduction in support costs <u>to the contractor</u> during the remaining period of the warranty. The government, as an interested bystander, receives a system with an optimum balance between initial costs and support costs (1: 8-21).

By far, the most important part of the Air Force 1974 RIW Guidelines was the section pertaining to RIW application criteria (21:9-11).

> ---the RIW approach would be in order for equipment that has a low reliability as well as a potential for further reliability growth. If there is room for reliability growth, the incentive feature of a RIW provision will have a greater affect on inducing growth.... Decision for RIW application should be made as early as possible in the acquisition cycle. The contractor must know early in the design phase that there may be warranty requirements so that he can make important tradeoffs. The following criteria may be used for selecting equipment as potential candidates for Reliability Improvement Warranty coverage. These criteria may be used for systems, subsystems, units, subunits, or even modules.
>
> (a) A warranty can be obtained at a price commensurate with the contemplated value of the warranty work to be accomplished.
>
> (b) Moderate to high initial support costs are involved.
>
> (c) The equipment is readily transportable to permit return to the vendor's plant or, alternatively, the equipment is one for which a contractor can provide field service.

(d) The equipment is generally self-contained, is generally immune from failures induced by outside units, and has readily identifiable failure characteristics.

(e) The equipment application in terms of expected operating time and the use environment are known.

(f) The equipment is susceptible to being contracted for on a fixed price basis.

(g) The contract can be structured to provide a warranty period of several years. This should allow the contractor sufficient time to identify and analyze failures in order to permit reliability and maintainability improvements.

(h) The equipment has a potential for both reliability growth and reduction in repair costs.

(i) Potential contractors indicate a cooperative attitude toward acceptance of an RIW provision and evaluation of its effectiveness.

(j) A sufficient quantity of the equipment is to be procured in order to make the RIW cost effective.

(k) The equipment is of a configuration that discourages unauthorized field repair, preferably sealed and capable of containing an Elapsed Time Indicator (ETI) or some other means of usage control.

(l) There is a reasonable degree of assurance that there will be a high utilization of the equipment.

(m) The equipment is one that permits the contractor to effect no-cost ECPs subsequent to the Goverment's approval.

(n) Failure data and the intended operational use data can be furnished the contractor for the proposed contractual period and updated periodically during the term of the contract.

The guidelines caveated the criteria by *stating that* equipment <u>did</u> <u>not</u> have to meet <u>all</u> criteria in order to apply an RIW. Naturally, this has caused a great deal of controversy and suggested warranty applications have included spectrum of systems ranging in complexity from a hydraulic pump to an entire aircraft weapon system (9:57) (10:1).

The Air Force Guidelines for RIW application were mirrored in an Assistant Secretary of Defense (I&L) Action Memorandum which directed the Services to undertake the trial use of RIWs in the "Electronic System/Equipment Program." The memorandum stated policy for funding RIWs and established essential elements in contractural RIW clauses, procedures for the determination of RIW cost effectiveness and methodology for evaluation of RIW applications (25: 1,2).

SECTION III

Specific Applications of RIW and Lessons Learned

F-111 Replacement Gyro

An example of an Air Force application of a Reliability Improvement Warranty is the F-111 Replacement Gyro currently under contract to Lear Siegler Inc (LSI).

Initially, the F-111 was equipped with General Electric attitude and reference systems of which the main component is the displacement gyro. These gyros had been procurred from General Electric on a sole-source negotiated basis. In 1969, it was determined that an additional buy of 332 units would be on a multi-year competitive basis and include a five year warranty, for reliability improvement. Two contractors, General Electric and Lear Siegler, responded of the 25 solicited. Lear Siegler was eventually awarded the contract (No F33657-69-C00662) and delivery of the units started in May 1971. Only 128 gyros were actually procured. Delivery was completed in May 1972. The warranty called for five years of service (by unit) or 3,000 ETI hours which ever occurred first.

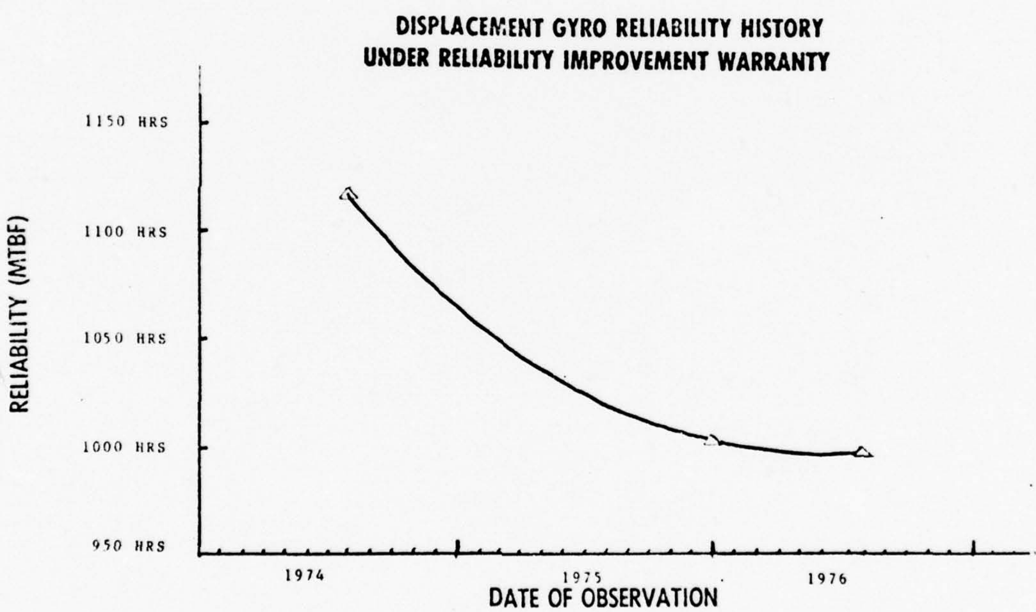
A significant savings on the initial procurement, in relation to previous General Electric units, was realized. LSI gyros were procured for $9,550 per unit vs $14,696 per unit (GE), a savings of 37%. The warranty purchased for the gyro was $2,200 per unit which spread over five years equates to 7% (per annum) of the acquisition price (17:9-7).

The displacement gyro meets all of the general guidelines laid down for application of RIW with the exception that 126 units did not appear to be a sufficient number to make the RIW cost effective. In fact, LSI, in responding to the Request for Proposal (RFP) had planned on supporting 332 units on an assembly line basis, but the buy was reduced to 126 causing LSI to utilize a shop repair method instead of assembly line procedures which they had costed in their proposal. The change in gyro handling procedures resulted on very high turn-around times averaging 80 days as compared with similar equipment averaging 33 days via assembly line repair (22:1).

Projected F-111 flying hours were curtailed during the period of warranty which caused low utilization rates of LSI units. The abbreviated failure history and resulting analysis for the initial period of warranty made it difficult for the contractor to initiate engineering changes to improve reliability. LSI had estimated costs based on achieving a 1500 hour MTBF but achieved only approximately a 1,000 hour MTBF. To further complicate LSI's performance, there were no economic escalation factors in the contract. (14)

With regard to increasing reliability, many sources compare the LSI gyro favorably to the GE unit and show a reliability growth to the last reported (15 July 1976)

MTBF of 995 hours as compared to 860 hours for the GE units. (1:9-8) (22:1) (14). The LSI gryo experienced an active decrease in MTBF during the warranty period notwithstanding ten engineering changes made solely to increase reliability. The following F-111 reliability pictoral is derived from LSI Semiannual and Annual Warranty Effectiveness Reports (26:1-4).



It is not clear what caused this decline in MTBF, whether it results from statistical anamolies, or premature gyro wear out (22:2) (14).

Another difficulty encountered with the FB-111 RIW experience is that as individual units reach limits of warranty there was no clear cut date that organic support must take over. For that reason and because spares, data, and ground test equipment are not purchased simultanously with the initial procurement, this transition to organic support is somewhat of an afterthought and is not given the planning and programming emphasis that the initial procurement is given. In the F-111 gyro case a transition to organic support was set for 26 Nov 76, however, due to lack of support planning the Air Force failed to long lead the data procurement and an extension of contractor support was in effect at the date of this writing (14).

ARN-118 TACAN

The most useful example of the current application of RIW is the ARN-118(V) TACAN. A TACAN is an airborne electronic navigation device which indicates bearing and slant range to a selected ground station. It fits the general guidelines for RIW application as the TACAN is composed of two "black boxes" and faults can be easily traced to the basic

units. In the Air Force the number of units installed may eventually exceed 8,500 so any significant increase in reliability will have a corresponding decrease in operations and support costs and manpower (10:51).

The Air Force's most predominant TACAN sets were the AN/ARN 21/52/65/T2 which have been experiencing a MTBF of less than 100 hours (3:8-1). Because of the low reliability of the TACAN and a need for smaller units in follow-on aircraft, RFPs were released in mid 1972 requesting bids for a developmental solid state TACAN that could be procured with either a Target Logistics Support Cost Clause or organic maintenance to be used with a Reliability/Improvement Warranty (3:8-2).

Development awards were made to Collins Radio and to General Dynamics Electronics (10:51). After the completion of development, an RFP was issued for production again requesting bids pricing for both the Target Logistic Support Cost and an RIW with an MTBF guarantee. Collins won the production contract, including a provision for RIW with MTBF guarantee, in July 1975 (10:52).

It is important to reiterate that the RIW provision was operative throughout the design and development of the TACAN and theory prevailing, the initial production models should have demonstrated an initially high reliability compared with older systems. Other RIW provisions included options for extension beyond the four year warranty period, a maximum

Turn-Around Time (TAT) of 15 days, a MTBF guarantee of 500 hours for the period of 22 to 33 months after contract award, increasing to 625 hours and finally to 800 hours during the 46 to 69 month period after award (14:31). Collins will have to provide additional spare units if the reliability objectives cannot be met (18:1-1).

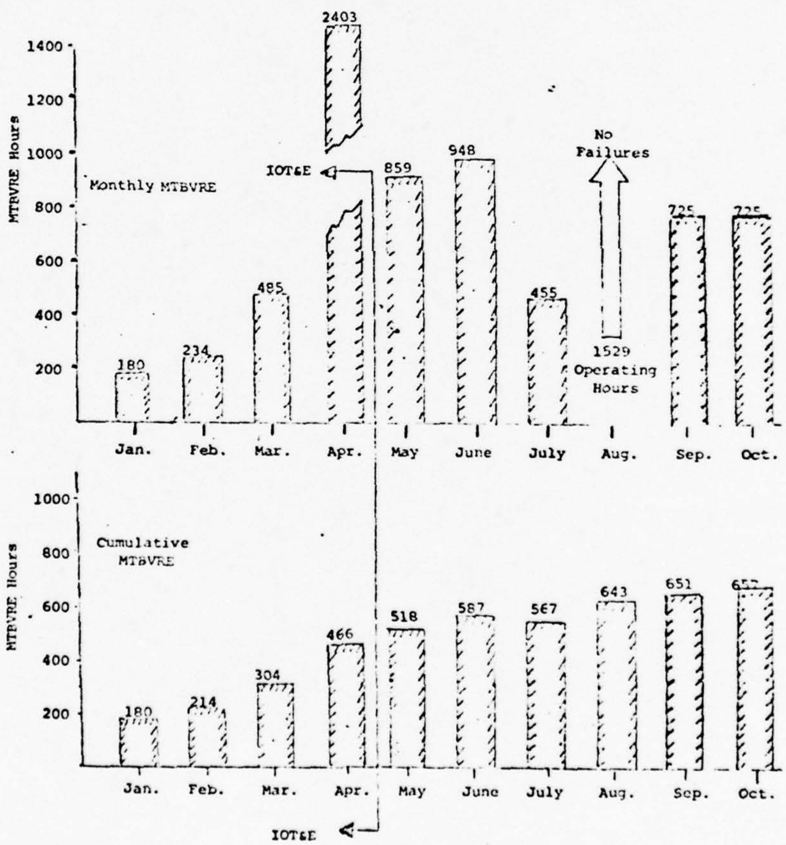
ARINC, a subsidiary of Aeronautical Radio, Inc., was placed under contract to obtain reliability data from initial installations of the ARN-118 and has submitted two formal reports, the latest of which was published in December, 1976. This data, though incomplete in some areas, is the first operational reliability data indicating the potential pay-off of the ARN-118 RIW provision (5:3).

Even though somewhat premature in the warranty life of the ARN-118 TACAN, it is appropriate to extract statistically supportable data and to draw some subjective conclusions based on the Air Force's early experiences with the units.

The test period covered by the ARINC report began with Initial Operational Test and Evaluation in January 1976 (which was completed on 30 April, 1976) and continued through 31 October 1976 (5:3). During the ten months of data collection, 57 TACAN units accumulated over 15,000 operational hours at three different operating locations (5:3, 17).

Data collected during this initial operational life of the ARN-118 indicates a cummulative Mean Time Between Vender Verified Repair Events (MTBVRE) of 657 hours (5:9). The below chart summarizes the reliability data from the ARN-118 TACAN during June through October 1976 (5:14).

ARN 118 TACAN
MEAN TIME BETWEEN VENDER REPAIR EVENTS (MTBVRE)
CY 1976



It is significant to note that there was only one instance of a good ARN-118 TACAN unit being sent to the manufacturer out of 24 units returned for repair (24:28). This 4% false alarm rate is significant since the warranty contains provision for the government being charged if the rate exceeds 30% (10:52). An underlying factor which may have been influencial is that the manufacturer had a representative at each of the three bases using the TACAN which may tend to invalidate any projected false alarm rates from this data (14). In fact, a close scrutiny of complaints by operators and "could not duplicate" maintenance actions indicated a basic unfamiliarity with the modes of operation of equipment which would tend to generate a high false alarm rate. The contribution by the presence of the contractor is unknown but expected to be high (5:19).

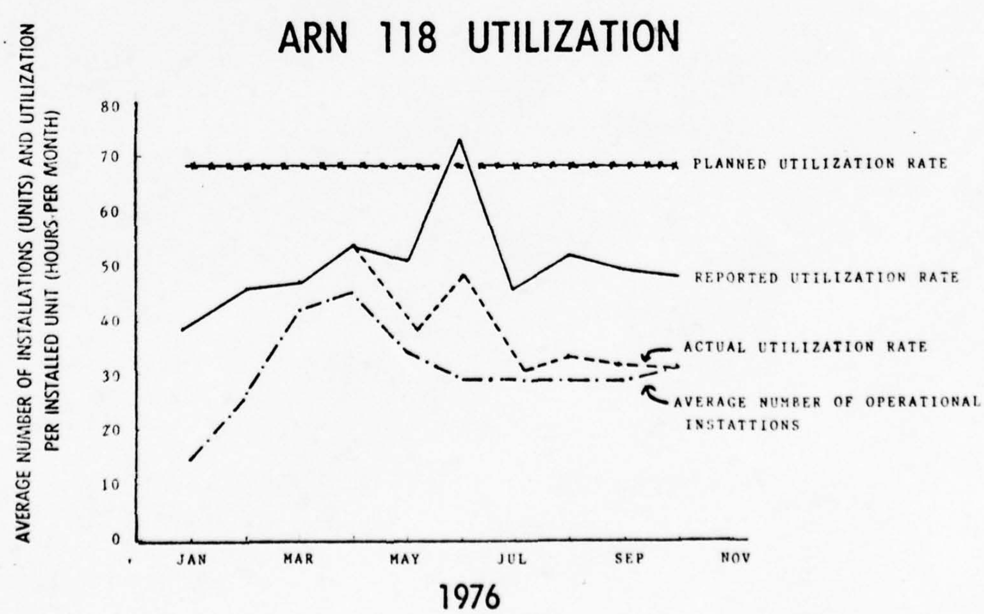
The improvement in reliability from a MTBVRE of 180 hours in January 1976 to 657 hours in October 1976 should not be totally attributed to a growth in reliability but partialy as a result of the system maturing.

In this author's opinion, a great deal of additional data is required and a reasonable evaluation of reliability growth can be made after two to three accumulated returns of TACAN units to the manufacturer. At the projected utilization rates of 68 hours per month and a MTBF guarantee of 800 hours, the average unit will return annually for repair. January 1979 should be an excellent data point to determine reliability growth of the units and fully assess the utility of the RIW application.

The cumulative MTBVRE of 657 hours is promising and indicates a <u>built</u> <u>in</u> <u>reliability</u> which should allow Collins to meet their initial reliability window of 500 hours beginning 12 April 1977 and ending 16 April 1978 (20: 3-1).

Other factors which have initially surfaced as a result of the TACAN RIW experience include a lower than expected utilization rate of delivered TACANs, basic unfamiliarity with RIW shipping procedures by field maintenance personnel, excessive shipping times to contractor's repair facility and manufacturer's turn-around (TAT) time exceeding projections. These factors will be discussed in the following paragraphs of this report section.

Utilization rate of TACANs had been projected at 68 hours per month (18:3-9). The below chart indicates the actual utilization (5:5,6,44).



The average number of operational aircraft which utilized the ARN-118 decreased significantly after the completion of IOT&E. This is primarily due to the grounding of 15 F-111 aircraft at Nellis AFB for Engine Time Compliance Technical Orders (TCTOs) (5:6). These grounded aircraft are not included in computations of average unit utilizations. If included, this utilization rate would have followed the dotted lines after April 1976 and would have been roughly only half the planned rate of 68 hours per month.

Many maintenance and supply personnel were unfamiliar with RIW procedures and were not certain where and how to ship the failed units even though each unit had been tagged with delivery instructions (8:56). As a result, shipping time to the contractor's repair facilities averaged 10.9 days including 9 shipments by Log Air which averaged 19.3 days. Conversely, contractor to base shipments averaged 4.5 days (5:23)

The contractor's TAT averaged 17.3 days which slightly exceeds the stipulated 15 days (5:30). If assessments had been called at this time, there would have been a small monetary adjustment. The current TAT is not considered excessive, however, when many more TACAN units enter the inventory, the contractor may find that he has to readjust his maintenance/repair facilities to

accommodate the heavier than projected workload incurred by the TAT.

It is too early in the TACAN RIW experience to make any hard predictions for reliability. It does appear that Collins has an excellent opportunity to meet the initial reliability goal of 500 hours (9). The user could help achieve higher reliability by insuring higher utilization rates early in the ARN-118 lifetime in order to produce failure data that will enable the contractor to locate failure modes and initiate engineering changes to increase reliability. This action is definitely in the contractor's best interest as it lowers his cost for the remainder of the warranty period and in the Air Force's best interest as it produces a more mature, more reliable system - at no additional cost.

SECTION IV

DISCUSSION OF LESSONS LEARNED

From the facts presented on the F-111 displacement gyro and the ARN-118 TACAN, it is apparent that Reliability Improvement Warranties are not the complete answer to the service's reliability and maintainability problems. They do hold a great deal of promise, if we apply the lessons learned from the previous applications of warranties.

Improvement of Testing Standards

The most direct answer to reliability standards is to improve testing to make it as representative of the operational environment as possible. It may well be worth the initial outlay of resources to build the necessary testing facilities and provide the early failure data when most engineering changes can be made on paper and not require removal and modification of operational systems. Such improvements in testing standards would be complementary to fine tuned reliability improvements which appear to be achievable through RIW procurements.

Encourage Application of Technology Toward Improvements in Reliability

It was stated earlier in this report that the second cause of poor reliability has been the Service's failure to emphasize the reliability requirement while pushing the state-of-the-art to achieve new levels of military capability.

The RIW provision has been shown to incentivize the contractor to balance the system, applying advances in technology toward reliability improvement as well as increases in capability. Direct pressure has been brought to bear on those technically tough reliability problems as they occur in on-going programs. This has been done through the Air Force's PRAM program. The acronym is an expression of the Air Force's intent to place major emphasis on Productivity, Reliability, Availability, and Maintainability of Aeronautical Systems and Equipment. The program has a stated intent to:

> . . . identify voids in current programs that could contribute to downstream reliability and maintainability problems and either to take corrective action or recommend to higher authority those actions that should be taken . . .strategic investments can be made which will *accelerate* technologies that are needed to make things last longer and cost less. . . PRAM is not just a 'do better' challenge to the Air Force but a very positive, dedicated and determined decision to do something now about reversing a trend that in the very near future could limit the operational effectivess of the United States Air Force (16:2).

Improved testing and resources directed at high pay-off areas of reliability improvement coupled with the RIW approach could synergistically yield significantly more reliable systems.

Difficulty in Pricing RIWs

Both the F-111 Displacement Gyro and the ARN-118 TACAN procurements discussed in this report qualify against all the popular tests for RIW application. Success in these

areas should not be applied too liberally to other systems without full cognizance of the difficulty in projecting and predicting failure rates and <u>the potential for reliability improvements.</u> This difficulty makes it almost impossible to cost out a RIW provision. Improved testing under realistic operational conditions as previously recommened could produce more reliability failure data and reduce the wide confidence interval of achievable failure rates. The incentive to improve testing in development is operative when the contractor expects a procurement warranty to be applied. In order to adequately price out the cost of an RIW with a guaranteed MTBF such as the ARN-118, the contractor must estimate the cost of a reliability improvement <u>from a projected reliability baseline.</u> At best, this will be a gross estimate, however, the range can be considerably narrowed if the contractor has a high confidence in a projected failure rate derived from realistic testing environments.

Maj Gen W.R. Nelson, Director of Maintenance, Engineering and Supply, Deputy Chief of Staff, Systems and Logistics, HQ USAF, in a comment to the Society of Logistics Engineers on 16 December 1976 referred to the problem of RIW pricing by saying:

. . .I am somewhat surprised in discussions with members of industry, to find that the RIW is perceived more as a threat than a business opportunity. Typically, the major concern appears to be with the magnitude of risk that RIW poses to the firm and with means to pass that risk back to the government or to sub-ties vendors. This concern is reflected in the risk premiums contained in the warranty pricing. In some instances, the risk premiums have been so excessive as to negate any utility in choosing the RIW approach (13:12).

Making the Warranty Work

As users of warranted equipment, we need to take more positive action to assure that the equipment is utilized at higher rates in order to produce failure histories. Even though warranty contracts can contain provisions similar to that for the ARN-118 TACAN which recompensate the government if systems are underutilized, it is in the Service's best interest to have reliability improvements made. The potential problem is always there, even with an MTBF guarantee that the contractor will swallow, through increased repair costs and provision of additional pipeline spares, a reliability problem identified late in the warranty period. Furthermore, when given the choice, a warranted unit should not be idle when an unwarranted unit is in service. Early reliability failure data is the internal lever of the RIW provision which starts the corporate wheels turning toward an eventual engineering fix. Notwithstanding the fact that warranties may expire on underutilized units with many hours of warranty operation remaining, the data is lost for follow-on blocks of the same unit.

Strategic Considerations and the Swedish Answer

The most troubling question to be answered still lies with the limitation that contractor support induces if military equipment is utilized at wartime rates from deployed locations. Many additional pipeline spares would be required because of the extended lines of communication and the dependence on the manufacturer's repair facility and technicians for trouble shooting. Procedures need to be developed for estimating these requirements and the production warranty contract should assure adequate pipeline spares are available. The other side of the strategic question centers around the military concern for a non-organic maintenance capability which might "be interrupted by strikes, war, or other phenomenon." (20: pages not numbered) The same arguments that are used against unionization of the military can be used against a military force dependent on unionized support for its weapon systems.

The Swedish Air Force applied a reliability improvement warranty for an Inertial Navigation System for the SAAB Viggen fighter aircraft. The Swedish approach used existing military depot facilities and personnel under supervision of a contractor to service and incorporate any necessary changes into the inertial units. Although the reliability performance of the inertial platform has been disappointing, it

does utilize the same logistical structure and shipping procedures are used as with non-warranted items (16:1-8). Furthermore, the Swedish concept would make the transition from contractor to organic support (a problem in the F-111 displacement gyro case) a smooth and gradual process. The Swedish application of warranty was described at the 1976 Annual Reliability and Maintainability Symposium, Las Vegas, Nevada, on 22 Jan 1976 as follows:

> It is based on a contractor-government partnership. Instead of assuming that either party is all knowing, it recognizes the contribution of each. Who better knows the hardware than the contractor that designed and built it? Who better knows maintenance than the government depot that has specialized in this art? This team approach is essential for maximum utilization of both the contractor's and the depot's talents and experience. If such an approach were used in the United States - 15 years experience in improving INS maintainability could be utilized and shared with the contractor (6:2-4).

The report on the Swedish approach further states:

> The Swedish approach accomplishes everything the RIW does and more. Their warranty decreases both contractor and government risk and takes advantage of government depot maintenance experience. This approach should be considered and compared to RIW. It should not be rejected out of hand (6:2-5).

Insufficient information exists to categorically state that the Swedish example should be applied within the U.S. It may be possible and even beneficial in a limited number of unique cases to service a warranty through the military

depot. The approach definitely deserves further and deeper investigation than the scope of this report allowed.

Other Lessons Learned

The ARN-118 RIW experience demonstrated a lack of understanding on the part of field maintenance and supply personnel on the unique procedures required in handling units under warranty. Special procedures need to be emphasized with appropriate increases in priority for handling and shipping approved and marked on the exterior of warranted units. Such procedures could be subject to inspection during unit evaluations.

SECTION V

CONCLUSIONS

SUMMARY

In investigating the causes of poor reliability, tracing the evolution of corrective instruments, and assessing the utility of the Reliability Improvement Warranty (RIW), there is no doubt that giant steps have been taken toward establishing an environment between the government and its contractors which will produce equipment with higher reliability and maintainability than previously achieveable.

In this report, it has been shown that basic roots of poor reliability are caused by:

1. State-of-the-art advances being generally applied to greater levels of weapon capability and not increases in reliability.

2. Developmental and qualification testing that did not represent actual operational environments with the resultant disparity between test results and operational failure rates.

3. The lack of incentive to the manufacturer of military equipment to initially build in and later improve reliability for an overall reduction in Life Cycle Costs of a weapon system.

Along with other instruments, the RIW has attacked the basic causes of poor reliability and many lessons have been learned from on-going applications. The major problems revolve around operational unfamiliarity with RIW procedures

resulting in poor utilization rates, lack of planning for transition to organic support, and strategic considerations stemming from dependence on non-organic support for critical weapon systems.

Estimating the cost of a warranty provision remains a problem for both the contractor and government.

The Swedish warranty approach, utilizing military depots and pipelines, eases the transition of a warranted item to organic support, gives the military a basic support capability which could be expanded in case of war or contractor labor/financial difficulties and establishes a partnership approach which may have high utility if applied judiciously in the United States. A detailed investigation of the methodology is required.

Recommendations

RIWs have demonstrated that they do contribute toward the overall objective of improved reliability, both built-in and acquired. An investigation of current applications has resulted in the following recommendations:

1. Continued emphasis on the improvement of testing and qualification environments to simulate in as near as possible the operational environment in which the equipment will ultimately be utilized.
2. Achieve greater cooperation from using commands to expeditiously install and utilize at higher rates, new equipment under warranty.

3. Educate and evaluate field maintenance and supply personnel on RIW concepts and handling procedures.

4. Establish higher priorities for shipping warranted equipment to contractor's repair facilities.

5. Evaluate the Swedish approach to RIW with a view to a test application and evaluation.

6. Continue to support through application of resources, technological advances in reliability improvement of critical components.

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